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Short Note

Evidence for an Oceanic Population of Killer Whales (*Orcinus orca*) in Offshore Waters of California and Oregon

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In the northeastern Pacific, sightings of small numbers of killer whales (*Orcinus orca*) of unknown ecotype have been sporadically reported during open ocean marine mammal surveys, pelagic birding expeditions, and high seas fishing operations (Pitman et al., 2001; Pitman & Dutton, 2004; Forney & Wade, 2006; Dahlheim et al., 2008; McInnes et al., 2021; Olson et al., 2023). However, it is unknown whether these oceanic killer whales belong to a mammal-eating ecotype of killer whale, an offshore fish-eating ecotype, or an offshore generalist type. We attempted to determine the ecotype of 49 unknown individuals observed during nine encounters from 1997 to 2021 in the deep oceanic waters far from the coastlines of California and Oregon (> 65 km) based on their foraging behaviors, prey species consumed, morphologies, and the prevalence of cookiecutter shark (*Isistius* sp.) bite scars. We hypothesize that these killer whales may represent a distinct oceanic subpopulation of transient killer whales or an undescribed oceanic population that feeds on marine mammals and sea turtles in the open ocean beyond the continental shelf break.

The sightings we analyzed came from four sources: (1) National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center (SWFSC) and Marine Mammal Laboratory (MML), Alaska Fisheries Science Center (AFSC) marine mammal stock assessment surveys, (2) a pelagic birding expedition, (3) a whale-watching ecotour, and (4) a marine mammal survey by the Marine Mammal Institute, Oregon State University (Pitman et al., 2001; Barlow & Forney, 2007; Moore & Barlow, 2014; Stierhoff et al., 2020; Carretta et al., 2021; McInnes et al., 2021; Olson et al., 2023). Surveys for birds and cetaceans primarily occurred during NOAA SWFSC stock assessments and covered thousands of kilometers but yielded few encounters with killer whales. All of the sightings occurred in oceanic waters (15 to 370 km offshore) between Astoria, Oregon (46° 16' N, -124° 7' W), and Point Conception, California (34° 26' N, -120° 26' W), and in waters ranging from 756 to 4,613 m deep (Figure 1; Table 1).

We plotted georeferenced locations of killer whales encountered using *ArcGIS Pro* and obtained water depth and bathymetric data for each killer whale encounter using the statistical package 'marmap' in the *R* software, Version 4.1.2 (Pante & Simon-Bouhet, 2013; R Core Team, 2021). The 'marmap' package allowed data to be directly downloaded from within *R* by querying the ETOPO1 database hosted by NOAA, while the 'get.depth' function provided water depth for each observation. Photo-identification of killer whales was analyzed from photographs opportunistically taken from NOAA vessels or from small boats launched from the larger vessel to pursue groups of animals. We relied on the unique markings and the shapes of the dorsal fin, saddle patch, and postocular patches to identify individual killer whales (Dahlheim, 1997; Olson & Gerrodette, 2008), and compared them to published and unpublished databases (Black et al., 1997; Dahlheim, 1997; Ford & Ellis, 1999; Olson & Gerrodette, 2008; Towers et al., 2019; McInnes et al., 2021, 2023).

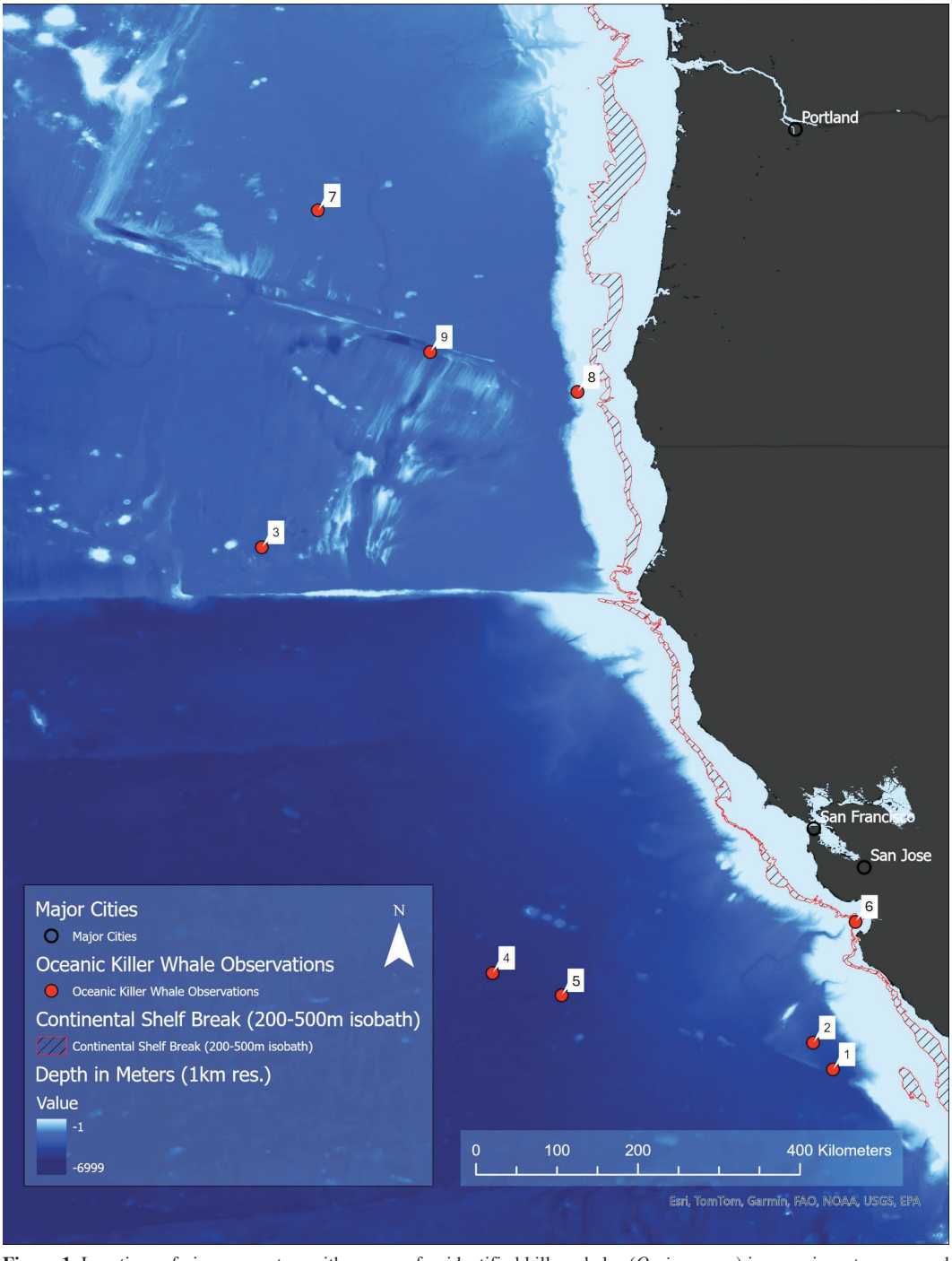

Figure 1. Locations of nine encounters with groups of unidentified killer whales (*Orcinus orca*) in oceanic waters seaward of the continental shelf break off California and Oregon. The continental shelf break (200 to 500 m isobath) is represented by the red hashed lines, and bathymetry is represented by shades of blue.

Table 1. Summary of nine encounters with killer whales (*Orcinus orca*) in oceanic waters off California and Oregon from 1997 to 2021. All sightings occurred seaward of the continental shelf break. Group composition indicates sex of individual killer whales, and group size indicates numbers of individuals present and photo-identified. Note that no animals were photo-identified during Encounters 2 and 3, and only seven of the killer whales were photo-identified during Encounter 1.

		Location								
No.	Date (d/m/y)	Lat.	Long.	From land (km)	Depth (m)	Group size	Group comp.	Killer whale identities	Prey species	Source
1	21/10/1997	35.09	-122.23	130	4,400	~35	2♂; 11♀; 2J; 2C	OCX001 OCX002 OCX003 OCX004 OCX005 OCX006 OCX007	*Physeter macrocephalus*	Pitman et al., 2001
2	26/10/1997	35.39	-122.45	83	3,800	5	1♂; 1♀; 3J	No IDs	*Physeter macrocephalus*	Pitman et al., 2001
3	3/11/2001	40.88	-128.56	350	3,178	7	1♂; 1♀	No IDs	*Dermochelys coriacea*	Pitman & Dutton, 2004
4	2/11/2014	36.16	-126.00	370	4,613	4	2♂; 2♀	OCX010 OCX011 OCX012 OCX013	*Kogia breviceps*	Olson et al., 2023
5	23/1/2020	35.92	-125.24	300	4,449	8	2♂; 4♀; 2J	OCX036 OCX043 OCX044 OCX045 OCX046 OCX047		This study
6	25/8/2021	36.73	-121.98	15	756	6	1♂; 3♀; 2J	OCX038 OCX039 OCX040 OCX041 OCX041A OCX042	*Grampus griseus*	This study
7	12/7/2015	44.61	-127.94	300	2,605	9	2♂; 4♀; 3J	OCX014 OCX015 OCX016 OCX017 OCX018 OCX019 OCX020 OCX021 OCX022	*Mirounga angustirostris*	This study
8	1/8/2018	42.60	-125.06	80	1,536	8	2♂; 4♀; 2J	OCX023 OCX024 OCX025 OCX026 OCX027 OCX028 OCX029 OCX030		This study
9	9/9/2021	43.05	-126.69	175	3,260	4	1♂; 3♀	OCX036 OCX043		This study

Of the nine encounters with the 49 previously undocumented killer whales, seven included photographs, and two only provided descriptions. Two of the 49 unknown killer whales seen in California were resighted a year later in Oregon (Encounters 5 & 9; Figure 1). Details and assessment of each encounter are as follows:

- *Encounter 1* — Occurred on 21 October 1997, ~130 km WSW of Morro Bay, California, in a water depth of 4,400 m (Figure 1; Table 1). Scientists aboard the NOAA research vessel *David Starr Jordan* encountered a group of killer whales attacking a pod of nine adult female sperm whales (*Physeter macrocephalus*; Pitman et al., 2001).

  The sperm whales were in a rosette formation—a circular antipredator behavior wherein the sperm whales position their heads towards the center and their flukes out towards the killer whales (Gemmell et al., 2015). Approximately 12 killer whales were initially involved in the hunt, but this number increased to an estimated 35 killer whales spread out over 3 km. Small concentrated groups of four to five killer whales randomly targeted and attacked individual sperm whales in the rosette. Hunting behavior included killer whales rushing in and lunging at the sperm whales or striking them from below. The killer whales would subsequently circle the rosette and retreat for several minutes, and then repeat the same hunting tactics. Fresh blood and an oil slick of animal fat could be seen at the surface following each attack. Multiple sperm whales had extensive injuries, with one individual having a 2 × 1.5 m flap of blubber that exposed the underlying flesh. One of the sperm whales was killed and dragged away from the rosette with several killer whales seen feeding on the carcass. The remaining sperm whales were believed to all have been seriously or mortally injured.

  Photographs of several killer whales showed the distinct oval pit wounds made by cookiecutter sharks (Figure 2), and analysis of images of dorsal fins and saddle patches did not match to known North Pacific killer whales identified off California or waters further north.

- *Encounter 2* — Occurred on 26 October 1997, ~83 km west of Point Lopez off central California in a water depth of ~3,800 m (Pitman et al., 2001). Scientists aboard the NOAA research vessel *David Starr Jordan* encountered five killer whales, including an adult male and adult female in proximity of two groups of sperm whales that were separated by 1 km.

Figure 2. Photo-identification pictures of OCX001 (left) and OCX002 (right), who were involved in the predation of a herd of female sperm whales (*Physeter macrocephalus*) 130 km west off Morro Bay, California, on 21 October 1997 (Encounter 1). Cookiecutter shark (*Isistius* sp.) bite marks are present on the gray saddle patch of both killer whales. (Photos provided by Robert L. Pitman, NOAA SWFSC)

The sperm whale group closest to the killer whales showed signs of agitation to the approaching killer whales. At this point, the furthest sperm whale group travelled quickly towards the agitated group. The adult female killer whale separated from her group and was sighted diving within meters of the congregated herd of sperm whales. At one point, an oil slick of animal fat was observed near where the female killer whale dove, suggesting that one or more sperm whales had been bitten. Throughout the encounter, additional sperm whales arrived from several kilometers away and joined the original two groups. The female killer whale at this point left the sperm whales and rejoined her travelling group, with no kill being observed in this event. Unfortunately, photographs from this encounter were not available to confirm photo-identification of individual killer whales.

- *Encounter 3* — Occurred on 3 November 2001, ~350 km west of Cape Mendocino, California, in 3,178 m deep water (Pitman & Dutton, 2004). An estimated group of seven killer whales were seen milling and diving in a large oil slick of animal fat, suggesting they had just completed a successful hunt. Several albatrosses (family Diomedeidae) were observed scavenging from a large turtle carapace on the surface, which was retrieved and confirmed to be from a leatherback turtle (*Dermochelys coriacea*). No photographs were available to identify and confirm the killer whale ecotype during this encounter due to difficult weather conditions and sea states (R. L. Pitman, pers. comm., 2021).

- *Encounter 4* — Involved four killer whales, two adult males and two adult females or subadult males, preying on a pygmy sperm whale (*Kogia breviceps*) on 2 November 2014, 370 km west of Monterey Bay, California, in a water depth of 4,613 m (Figure 3A; Olson et al., 2023). The group was sighted during a shipboard marine mammal survey conducted by NOAA SWFSC (Barlow, 2016). Observations continued for 51 min until the killer whales moved off from the predation site and the ship resumed its line-transect survey.

  The attack was well underway when first sighted as shown by an oily slick on the water and a circling flock of seabirds. Approximately 100 black-footed albatrosses (*Phoebastria nigripes*) and several northern fulmars (*Fulmarus glacialis*) were identified feeding on tissue at the surface (Figure 3B). As the ship approached, much splashing and blood were seen, followed by a partial breach of a medium-sized cetacean (species unidentified) along with a tall geyser of blood.

  The prey species was identified genetically from recovered tissue as a pygmy sperm whale. Images of the killer whales could not be matched to known photo-identified North Pacific ecotypes and were subsequently given the new identification designations OCX010, OCX011, OCX012, and OCX013 (McInnes et al., 2021). Acoustic data recovered from two sonobuoys deployed after the kill contained killer whale echolocation clicks and two pulsed calls (with no other types of vocal activity). The pulsed calls were most similar to the offshore killer whale ecotype (Foote & Nystuen, 2008; Rice et al., 2017) but were insufficient to confirm the ecotype.

  The four killer whales had notable external morphologies that differed in saddle patch shape: three had narrow saddle patches (typical of tropical killer whales; Figure 3C; Baird et al., 2006; Olson & Gerrodette, 2008) and the fourth had a wide saddle (typical of transient killer whales; McInnes et al., 2021). The dorsal fins of the males resembled the transient ecotype with pointed tips. All four killer whales had cookiecutter shark bite scars, and two of them displayed fresh bite wounds.

- *Encounter 5* — Occurred on 23 January 2020, ~300 km west of Monterey Bay, California, in a water depth of ~4,449 m when eight killer whales were sighted during an offshore pelagic bird survey. The group consisted of one adult male, four adult females or subadult males, and three juveniles (Figure 4). The dorsal fin shapes of multiple killer whales were pointed or moderately round, and saddle patches were large and uniformly gray—most closely resembling those of the transient ecotype. None of the eight killer whales were known individuals. However, one of the encountered adult males (later cataloged as OCX036) and an adult female or subadult male (OCX043) were resighted a year later 175 km west of Bandon, Oregon (see Encounter 9).

- *Encounter 6* — Occurred during an ecotourism expedition in Monterey Bay, California, on 25 August 2021 when six killer whales were encountered over the deep Monterey Submarine Canyon in a water depth of ~756 m. Group composition included one adult male, three adult females or subadult males, and two juveniles. The six killer whales were spread out and travelling west

Figure 3. (A) Adult male oceanic killer whale OCX011 surfacing in the open ocean swells among several black-footed albatross (*Phoebastria nigripes*) approximately 370 km due west of Monterey Bay, California, on 2 November 2014 (Encounter 4); (B) close to 100 black-footed albatrosses and several northern fulmars (*Fulmarus glacialis*) were documented in the vicinity of the predation event; and (C) adult male oceanic killer whale OCX012 diving to feed on a successful predation event involving a pygmy sperm whale (*Kogia breviceps*). (Photos provided by Paula Olson, NOAA SWFSC; see Olson et al., 2023)

in the middle of the bay and at a steady 4 to 5 km/h. A herd of 40 Risso's dolphins (*Grampus griseus*) were reported 2 km ahead in the direction the killer whales were travelling. The killer whales began to accelerate with shorter synchronous dives. As the distance between the killer whales and the Risso's dolphins decreased, the dolphins began to high-speed porpoise with individuals spread out in front formation, producing a large wall of white water ahead of the killer whales (stampede behaviour; Read et al., 2022). Two killer whales flanked the herd of Risso's dolphins on either side, with one killer whale leaping high into the air behind the herd.

Eventually, a Risso's dolphin was separated from the group and pursued by two adult female or subadult male killer whales. The dolphin leaped into the air on two occasions and was closely followed by one of the killer whales. As the Risso's dolphin began to fall behind, one of the killer whales surfaced beneath the dolphin and launched it into the air (Figure 5). The killer whale performed this behavior three times before securing the dolphin and pulling it beneath the surface. The Risso's dolphin was last seen being carried in the mouth of one of the killer whales, which was accompanied by the five other killer whales. All six killer whales had bite scars from cookiecutter sharks along with

Figure 4. A group of eight unidentified oceanic killer whales sighted approximately 300 km west of Monterey Bay, California, on 23 January 2020 (Encounter 5) (*Photo credit:* John Garrett)

Figure 5. Action sequence showing an adult female or subadult male oceanic killer whale OCX040 attacking a Risso's dolphin (*Grampus griseus*) in Monterey Bay, California, on 25 August 2021 (Encounter 6) (Photos provided by Slater Thomas Moore, Slater Moore Photography)

pointed dorsal fins and solid gray saddle patches that resembled the transient ecotype. While it is possible that these killer whales might be part of the outer coast transient population that uses California waters, none of these whales could be matched to known North Pacific killer whales and were never observed in association with transient ecotype killer whales in our 13-y study period.

- *Encounter 7* — Occurred on 7 December 2015 while nine killer whales travelled in a tight formation ~300 km west of Newport, Oregon, in ~2,605 m water depth. NOAA SWFSC scientists reported that the group included two adult males, four adult females or subadult males, and three juveniles. At least five black-footed albatrosses were also seen following the group as they travelled in a westward direction. At one point, the largest adult female or subadult male changed directions and began moving east ahead of the other killer whales. After several minutes, this individual changed direction again and made an aggressive shallow surface lunge, grabbing an unidentified prey species. The rest of the killer whales then rejoined this whale and began swimming in a double front formation, with an adult male in the rear.

  When the killer whale surfaced, it was carrying the carcass of a female or subadult male northern elephant seal (*Mirounga angustirostris*; Figure 6A). A cloud of blood was seen at the surface of the water when the killer whale dove (Figure 6B). Two juveniles began socializing by spy hopping (raising their heads out of the water) and tail slapping at the surface. The female or subadult male

Figure 6. (A) An adult female or subadult male killer whale OCX022 holding a northern elephant seal (*Mirounga angustirostris*) in their mouth (Encounter 7); (B) subsequent photograph showing blood at the surface during a successful predation; and (C) photo of adult female or subadult male killer whale OCX015 feeding on a northern elephant seal while three black-footed albatrosses scavenge on intestines floating just beneath the surface. Encounter took place approximately 300 km due west of Newport, Oregon, on 12 July 2015. (Photos provided by NOAA SWFSC)

killer whale then released the carcass, and another killer whale grabbed it. At this point, three black-footed albatrosses landed near the floating carcass and began feeding on the intestines floating at the surface (Figure 6C).

Photographs of three of the killer whales showed evidence of cookiecutter shark bites, and all members had large uniform gray saddle patches typical of the transient ecotype. Two of the killer whales had rounded dorsal fins that resembled the offshore killer whale ecotype. None of the nine killer whales could be photo-identified.

- *Encounter 8* — Involved eight killer whales encountered on 1 August 2018, ~80 km west of Ophir, Oregon, in a water depth of ~2,605 m during a NOAA SWFSC marine mammal stock assessment survey. Group composition included two adult males, four adult females or subadult males, and two juveniles (Figure 7A). Two killer whales had cookiecutter shark bite marks, with one female or subadult male having a fresh wound (Figure 7B & C). Several killer whales had pointed transient-like dorsal fins, while others had moderately rounded dorsal fins. Saddle patches were large and uniformly gray. The killer whales were noted to be travelling, and no predation was observed. None of the eight killer whales could be matched with previously photo-identified individuals.

- *Encounter 9* — Involved four killer whales encountered on 9 September 2021 175 km west of Bandon, Oregon, in ~3,260 m water depth by scientists with Oregon State University's Marine Mammal Institute. The group composition included one adult male and three adult females or subadult males. Two killer whales in the group were identified as OCX036 and OCX043 (Figure 8) that were previously seen 300 km offshore of Monterey Bay, California, in 2020 (during Encounter 5). Rough seas and weather conditions made it difficult to collect behavioral data.

An Oceanic Population of Killer Whales?

Knowledge about killer whales inhabiting open ocean environments is limited to relatively few encounters. The nine encounters reviewed and presented herein provide information on the feeding behavior, prey species, and the potential habitat use of killer whales in oceanic waters off California and Oregon. Encountering killer whales in oceanic environments is relatively rare (Forney & Wade, 2006) due to the expansiveness of this environment, the low densities and high mobility of killer whales in the open ocean, and limited effort to survey killer whales. Each encounter is therefore an important opportunity to gather new insights into the ecology, behaviour, and diet of these predators in oceanic waters.

Along the coasts of California and Oregon, three distinct killer whale ecotypes termed *residents* (fish-eating), *transients* (mammal-eating), and *offshores* (preference for shark and other large fish species) are known to occur (Baird & Stacey, 1988; Baird & Dill, 1995; Baird, 2000; Barrett-Lennard & Ellis, 2001; Dahlheim et al., 2008; Ford et al., 2011; Rice et al., 2017; McInnes et al., 2023). They are distinct from each other in terms of genetics, acoustics, morphology, behavior, distribution, and prey preferences. While resident killer whales have been sporadically documented in offshore continental shelf waters near commercial fishing banks (Rice et al., 2017; Riera et al., 2019), only the offshore and transient ecotypes are believed to inhabit oceanic waters seaward of the continental shelf of the region (Dahlheim et al., 2008; Ford et al., 2013; McInnes et al., 2021).

Observations of killer whales occurring off California and Oregon have typically involved the transient and offshore ecotypes (McInnes et al., 2023). Transient killer whales usually sighted in this region belong to the West Coast population that is distributed from southeast Alaska to southern California (Ford & Ellis, 1999; Muto et al., 2020; McInnes et al., 2021). The West Coast population is thought to comprise two subpopulations that occasionally associate with each other but have heterogenous distributions and habitat use patterns—the *inner coast* and *outer coast* transient subpopulations (Ford et al., 2013; Muto et al., 2020; McInnes et al., 2021). The inner coast transient subpopulation is predominantly encountered in shallow continental shelf waters, < 10 km from shore, where they specialize in hunting pinnipeds and small cetaceans (Baird & Dill, 1995; Ford & Ellis, 1999; Dahlheim & White, 2010; Houghton et al., 2015; McInnes et al., 2020); while the outer coast subpopulation has been predominantly documented feeding on pinnipeds, oceanic dolphins, and large cetaceans in deep pelagic waters near the continental shelf break and submarine canyons (McInnes et al., 2023).

In contrast to the transient ecotype, the offshore ecotype killer whale comprises a single genetically distinct population distributed from the Bering Sea, Alaska, to southern California (Dahlheim et al., 2008). They have been typically sighted in continental shelf waters (near shallow banks, the continental shelf break, and coastal submarine canyons) off California in the winter months, and off British Columbia and Alaska in the summer (Dahlheim et al., 2008; Ford et al., 2014; Schorr

Figure 7. (A) A group of unidentified killer whales were encountered ~80 km due west of Ophir, Oregon (Encounter 8); (B) image shows an adult female or subadult male killer whale OCX026 with a fresh cookiecutter shark wound; and (C) three unidentified killer whales travelling together in offshore Oregon waters. (Photos provided by Jim Carretta, NOAA SWFSC)

Figure 8. Killer whale OCX043 encountered with three other killer whales 175 km west of Bandon, Oregon, on 9 September 2021 (Encounter 9). This killer whale was sighted previously 300 km offshore of Monterey Bay, California, on 23 January 2020. (*Photo credit:* Robert L. Pitman, Oregon State University)

et al., 2022). They typically travel and forage in large groups of > 50 individuals, and they are thought to feed primarily on higher trophic-level elasmobranch species, including Pacific sleeper shark (*Somniosus pacificus*), bluntnose six gill shark (*Hexanchus griseus*), blue shark (*Prionace glauca*), and spiny dogfish (*Squalus acanthias*).

The killer whales we encountered could not be photo-identified or matched in association with any known transient or offshore killer whales. They also occurred much further from shore than has been reported for transient killer whales in our study region but within the range of what has been reported for offshore killer whales (Dahlheim et al., 2008). The majority (46 of 49 killer whales) also had oval/crescentic bite scars from cookiecutter sharks, which are a mesopelagic parasitic shark that inhabits deep offshore tropical and subtropical regions in water temperatures ranging from 18° to 26°C (Jones, 1971; Nakano & Tabuchi, 1990; Pepperell & Harvey, 2010; Best & Photopoulou, 2016). These wounds varied in shape and color with older scars being black or white in coloration and newer fresh bites being pink and showing fresh epidermal and adipose tissue.

The presence of cookiecutter shark wounds provides indirect evidence that these unknown killer whales had spent time in warmer oceanic waters. Further north, in the Aleutian Islands, Alaska, and Bering Sea, transient killer whales have also been observed making large-scale open ocean movements. Three killer whales equipped with satellite tags (two tagged in the Aleutian Islands and one tagged in the Pribilof Islands) moved rapidly from cold-temperate coastal waters to the subtropical waters of the central Pacific (Matkin & Durban, 2011). Similar to the unidentified killer whales in our study, transient killer whales in the Aleutian Islands and Bering Sea also had cookiecutter shark bite scars, providing additional evidence of large-scale open ocean movements (Matkin & Durban, 2011).

In terms of morphology and pigmentation patterns (which are known to differ between ecotypes; Baird & Stacey, 1988; Emmons et al., 2019), the sizes and shapes of the dorsal fins and saddle patches of the 49 unidentified killer whales bore some similarities to both transient and offshore ecotypes. However, their physical appearance also differed within and between groups of killer whales. The shape of the dorsal fins varied, with some individuals having the characteristic pointed dorsal fin of transients and others presenting well-rounded offshore ecotype dorsal fins. In addition, the shape and pattern of the gray saddle patch also varied, with some killer whales having large uniformly gray saddle patches and others having smooth, narrow saddle patches similar to those seen in killer whales in tropical regions (Olson & Gerrodette, 2008). None of the unknown killer whales had open saddle patches, and most (40 of the 49 killer whales) had postocular patches that were medium-sized, generally oval, and ran horizontal to the body axis.

In terms of diet and foraging behaviors, none of the unidentified killer whales were observed preying on fish or sharks. Except for the turtle (Encounter 3), the killer whales hunted marine mammal species associated with deep oceanic waters. The attacks on adult female sperm whales (Encounters 1 & 2) are particularly notable given that attacks on sperm whales have never been reported for transient killer whales off California and Oregon. Female sperm whales are significantly smaller than males, tend to occur further offshore in deeper, warmer waters (15°C, > 1,000 m), and often travel in herds with vulnerable calves (Pitman et al., 2001; Moore & Barlow, 2014, 2017; Carretta et al., 2021). These factors could provide killer whales inhabiting oceanic waters off California and Oregon with a significant food resource during times when female sperm whales are present and when other prey species are scarce or patchy in distribution.

Smaller species of cetaceans also appeared to be an important food source for the killer whales we observed (Encounter 6). Risso's dolphins, Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), northern right whale dolphins (*Lissodelphis borealis*), and common dolphins (*Delphinus delphis*) form large schools that are distributed far offshore of California and Oregon. Oceanic dolphins frequently use echolocation to locate and communicate with each other while searching for widely distributed prey in the open ocean (Vaughn-Hirshorn, 2019). Killer whales may rely on passive listening to detect the acoustic signals produced by dolphins, enabling them to follow the movements of dolphin schools over large spatial scales.

Northern elephant seals are another open ocean species (Block et al., 2011; Beltran et al., 2022) that may be a valuable food source for oceanic killer whales (Encounter 5). They are relatively defenseless, large, and have energy-rich blubber that would provide a substantial amount of food for killer whales.

All of the attacks and kills by the 49 unknown killer whales were on marine mammals, except the one on a leatherback turtle—a species that navigates the open Pacific between foraging grounds off the California coast and breeding grounds in the western Pacific (Benson et al., 2011; Block et al., 2011). It is noteworthy that predation on fish was not observed during any of the encounters with the unidentified killer whales. However,

it is difficult to observe such events given that they primarily occur beneath the surface where evidence of scales and other tissues are often found following successful hunts as shown by studies of resident and offshore killer whales (Ford & Ellis, 2006; Ford et al., 2011). Therefore, the possibility that the killer whales in our study consume fish or sharks cannot be ruled out.

In conclusion, we could not match or associate any of the 49 individual killer whales with any known photo-identified killer whales in the northeastern Pacific. This suggests that these killer whales may belong to one or more populations that exhibit a primarily oceanic distribution. Morphologically, the individuals we encountered shared physical similarities with both transient and offshore ecotypes but were not a perfect fit with either. Diet wise, all observed predation events involved open ocean species of marine mammals and a sea turtle, which differs sharply from the sharks and smaller teleost species consumed by offshore killer whales.

Based on the foregoing, we suspect that the unknown killer whales we encountered may represent an oceanic subpopulation of transient killer whales—or a previously undescribed generalist ecotype that feeds on marine mammals and sea turtles—that primarily frequents waters seaward of the continental shelf break. It may be that killer whales inhabiting low productive areas such as the open ocean and tropical marine ecosystems are less specialized than the North Pacific neritic populations that specialize on fish or marine mammals. However, further systematic offshore surveys in oceanic habitats using satellite tagging, genetics, acoustics, and photo-identification methodology are needed to confirm our suppositions.

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